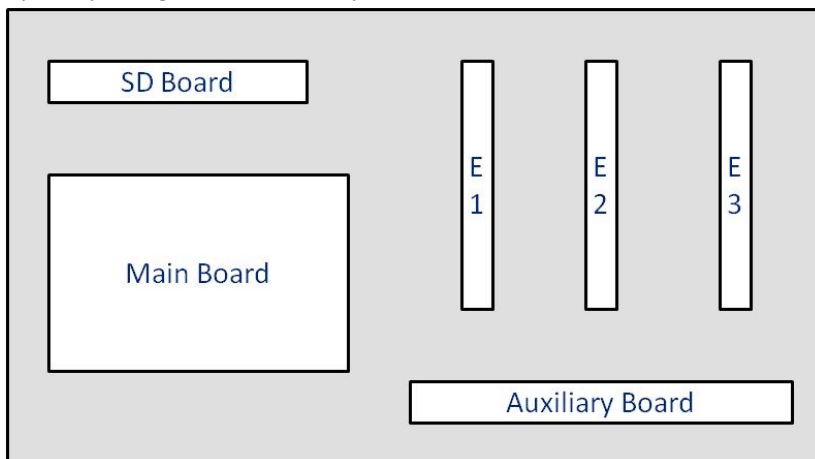1. Overview

   This user manual will provide the user with an overview of the microcontroller (MCU) based potentiostat developed in the Angenent Lab, and instructions for its use.

   1.1. Parts

   Upon opening the black box, you will find six (6) different boards, arranged as shown below:

   The function of each board is:

   Main Board – Contains the power for the device and houses the microcontroller. Connects to and controls all other boards. The liquid crystal display (LCD) connects to this board.

   SD Board – Contains the secure digital (SD) card for data storage. Contains the switch to turn the LCD screen on/off.

   E1, E2, E3 – Contains circuitry for electrodes 1, 2, and 3, respectively.

   Auxiliary Board – Contains circuitry to process signals between E1, E2, & E3 and the main board.

   1.2. Additional Components

   In addition to the black box, there is a liquid crystal display (LCD) screen that plugs into the main board for real-time feedback and adjustments. Finally, you will need a small flathead screwdriver to adjust applied potentials.

2. Functions

   2.1. LCD Operation

   Plug the LCD wire into the main board. The LCD should turn on, but not display anything cohesive. To activate the LCD, flip the switch on the SD card board. This will reinitialize the LCD in its default state.

   In the default state, you can see the date and time settings of the CPU and an operating parameter call shift.
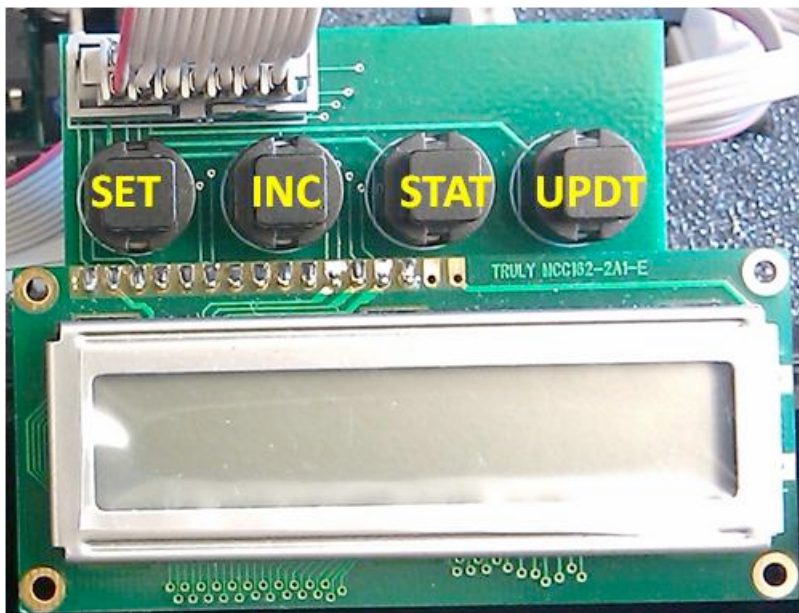
There are four buttons on the board. In order from left to right, these buttons are:

SET button   Goes into set mode so user can change data

INC button   Increments value

STAT button   Rotates between the clock screen and the electrode data

UPDT button   Quickly updates electrode data

2.2. Adjusting the clock

To adjust the clock, hold the SET button down while on the clock screen. This button will scroll through the date and then the time to make changes. To increment the value that the cursor is currently at, press and hold the INC button. Holding it down will allow the value to continue to increment. After the correct time is set, continue to hold down the SET button until the cursor disappears. This will return the potentiostat to its normal operating mode and print a message on the SD card noting that the time was changed.

2.3. Checking the readings

You can check the current status of each channel. To scroll between the time indicator and the electrode statuses, press the STAT button. This will scroll through each electrode channel before returning to the date channel. Each status channel will display the last taken measurement of the voltage being applied across the electrode and the current being read in. Pressing the UPDT button will cause the CPU to take a new measurement at that electrode and display the results on the LCD screen. No data will be written to the SD card. The default setting is to apply a negative voltage across the electrode. If the user desires to apply a positive potential, press the SET key. A zero represents a negative potential while a one represents a positive potential. The next number is the resistance applied to multiply the current. Change the value to the correct resistance. Holding down the SET key will return the screen to displaying the current.

2.4. Removing the LCD screen

To remove the LCD screen, flip the switch on the SD card board down and pull the LCD screen and cable out of the main board. The switch will stop data from being sent to the LCD.

2.5. Resetting the SD Card

Anytime after the SD card is removed, it will need to be reset. To do this, pull the SD card board out and push the black button on it. If the LCD screen is plugged in and on, and the screen is currently in the clock view, the second line of the LCD screen will read "SD card reset."

2.6. Adjusting the applied potential

2.6.1. Polarity and current range
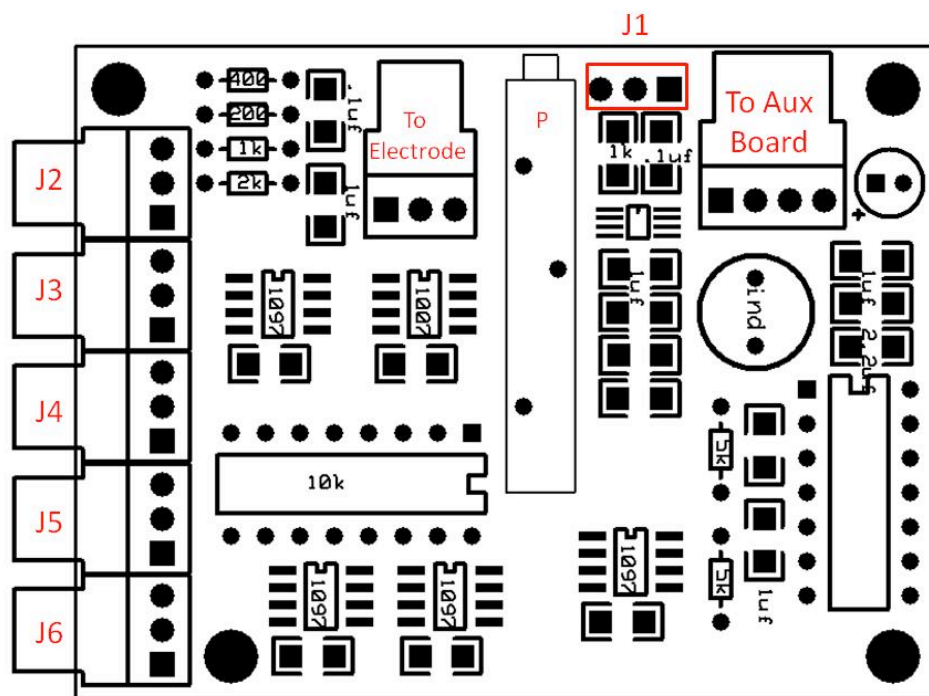
The electrode board is showed above with the applicable connections and jumpers.

J1 should always be connected to from the center pin to the right pin. J2 and J3 control the current range, and can be adjusted as described in the table below. The default setting should be for a 1mA range.

Current Range	Jumper Setting
200 µA	J2, Center-Left pins connected
400 µA	J2, Center-Right pins connected
1 mA	J3, Center-Left pins connected
2 mA	J4, Center-Right pins connected

Note: Changes in current range should be noted by the user and changed via the LCD screen (see section 2.3).

Jumpers 4, 5, & 6 control the polarity of the applied voltage to the working electrode. To apply a positive voltage, connect the center pin to the right pin of J4, J5, and J6. To apply a negative voltage, connect the center pin to the left pin of J4, J5, & J6.

Note: Changes in polarity should be noted by the user and changed via the LCD screen (see section 2.3).

Note: The SD card and LCD screen display will always show a 1 kΩ resistance calculation. If the resistance is not at 1 kΩ, the LCD screen data and the SD card data will be off by the ratio {set resistance/1 kΩ}. The resistance value is stored to the SD card so that the correct readjustments can be made by the user when analyzing data.

2.6.2. Magnitude

To adjust the magnitude of the applied potential, use the screwdriver to turn the potentiometer (labeled P in diagram). To decrease the magnitude, turn the dial clockwise. To increase, turn the dial counter-clockwise. Use the LCD screen (section 2.3) to assist in setting the correct potential.

2.7. Adjusting the shift

The shift is an operating parameter that may need to be adjusted by the user. For normal operation under a 1 mA current range, the shift should be set to 550 mV, making the range of readable currents -550 µA to 550 µA. To adjust the shift to the correct value, use the potentiometer located on the auxiliary board. To decrease the magnitude, turn the dial clockwise. To increase, turn the dial counter-clockwise. Confirm the correct value using the LCD screen (section 2.1).

2.8. Programming the Microcontroller

If the need to program the chip arises, attach the programming device to your PC (via USB) and connect the other end to the 6 pins found near the bottom of the main board. The red wireshould connect to the left side of the board. Make sure that the jumper connector below the 6 pins is inserted, otherwise the chip will not program.

Open up AVRstudio. Go to the project folder and open up *potentiostat.aps*. The project should open up. Follow the instructions found on this website to make sure that the data is stored correctly. http://winavr.scienceprog.com/avr-gcc-tutorial/using-sprintf--function-for-float-numbers-in-avr-gcc.html (instructions begin near the bottom, starting with "You may ask what to do with AVRStudio settings, where makefile is generated automatically. Well things are simple too in this situation." Then go to Project>>Configuration Options and make sure that the device is "Atmega644" and the frequency is set to "16000000" Hz.

The potentiostat is currently set to record data every hour. To change this setting, go to source files on the left bar. And open *main.c*. Right at the top there is a macro called *record_trigger()*. This tells the device when to record data. To set which hours you want the potentiostat to record, change the (hour==xx) to be whatever hours you want. If you want it to record every single hour, remove all the hour lines. Keep the msec, sec, and min, instructions, as ensures that it records only once in that time and not constantly.

Hit F7 to program the device. If there are errors make sure you go and fix them.

Go to Tools>>Program AVR>>Connect. Select the platform "AVRISP mkII" and Port "USB." Hit connect. A new window should appear. Go to the Program tab and in the Flash menu, hit the … to browse the file location. Go into the project folder "/default/potentiostat.hex". Then hit the program button. This should program the device.

3. Connections

3.1. Connections between boards

The unit should have all connections in the correct position at the beginning of use, but if the need arises to unplug or re-connect the boards, the correct configuration is outlined below:
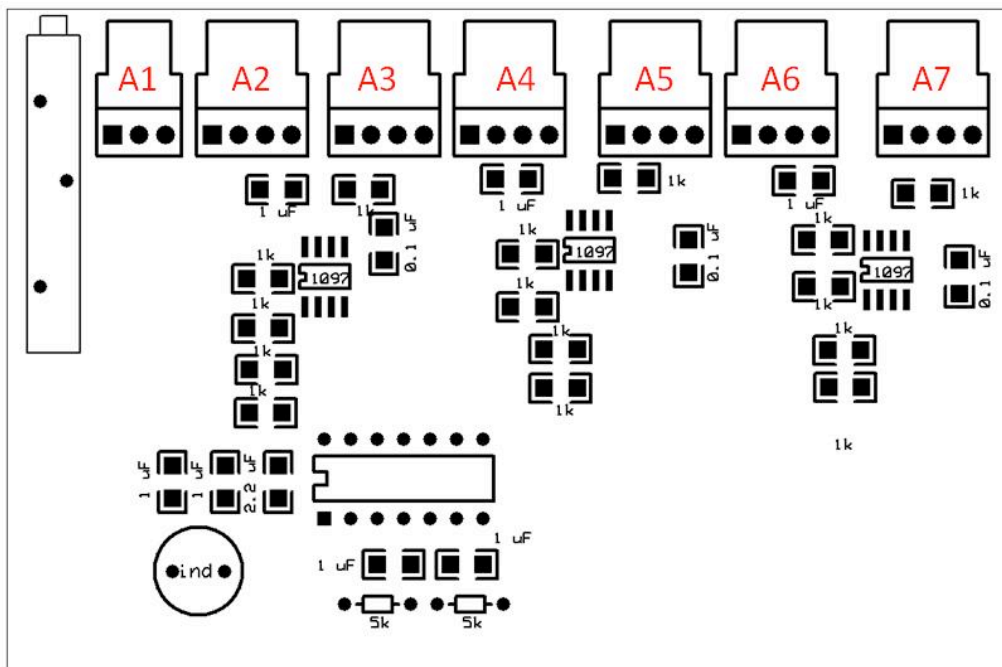
Auxiliary Board Connections:

A1 – Connects to main board via 3-prong connector

A2 – Connects to E1 board via 4-prong connector

A3 – Connects to main board port labeled 'E1'

A4 – Connects to E2 board via 4-prong connector

A5 – Connects to main board port labeled 'E2'

A6 – Connects to E3 board via 4-prong connector

A7 – Connects to main board port labeled 'E3'

The SD board connects to the main board via the 10-prong connectors on either board.

3.2. External connectors

There are three external connectors: a 6-pin connector, a 3-pin connector, and (depending on the unit) either a 2-pin or another 3-pin connector labeled with blue tape. The six pin connector connects to the working and counter electrodes. The unlabeled 3-pin connector connects to the reference electrodes. The labeled 2- or 3-pin connector connects to the power source.